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DESIGN FABRICATION AND CONTROL OF A HEXAPOD ROBOT

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ABSTRACT

The technological advancements at the global level have put in a large demand for robots in various industrial applications. The aim of the proposed work is to build a six-legged walking robot that is capable of performing basic mobility tasks, such as walking forward and backward and perform rescue operation in mines. The flow of work is comprises of CAD software, Solid works design of robot, fabrication and control. Later velocity of hexapod is tested and the model with one degree of freedom is validated. The complex motion done by hexapod is enhanced by adding sensing components. This modification would enable it to be implemented in the defense applications, automobile industries and machine tooling. Beyond this type of application, hexapod walking is used in a wide variety of tasks such as forests harvesting, in aid to humans in the transport of cargo, as service robots and entertainment.

***KEYWORDS**: Hexapod Robot, Degree of Freedom, CAD Software & Industrial Applications*

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Original Article

INTRODUCTION

In the event of a natural or man-made disaster, the first responders have to risk their lives when entering the disaster site. The ability of a robotic system to first enter and assess the disaster site, before a first responder enters, would reduce this risk [1]. The ability of the robotic system to provide essential data about the disaster site can also aid in the decision-making process. This was demonstrated following the attacks on the World Trade Centre in the United States, when small robotic systems were sent into sections of the collapsed buildings to search for survivors [2][3][4]. More recently at the Fukushima nuclear power plant disaster in Japan, robotic systems provided valuable data about the state of the nuclear reactor after the incident [5].

The need to reduce the risk to humans is not limited to natural or man-made disasters in urban areas, but is equally relevant in the mining sector. In the event of an explosion or a tunnel collapse in a mine, a robot could conceivably be deployed to assess the air quality, determine the structural integrity of the tunnel, and search for survivors. In addition, the robotic system could produce accurate 3D maps of the tunnels and the collapsed areas. Providing the rescuers and mine engineers with data on how to proceed with the rescue operation, and what equipment and resources would be needed.

Reducing the risk to humans is not only limited to a disaster in a mine, but in the everyday operation of the mine. After drilling, placing the explosives and finally detonating a charge, a safety officer has to enter this newly blasted area of the mine and assess its safety. The potential for injury is high as there are loose overhead rocks that must first be removed or secured.

Currently, the instrumentation to scan the mined area has to be carried to just outside the newly blasted

area, the sensor is then set up and the necessary data collected. Not being able to enter the newly blasted area restricts the range of the scans and limits the viewpoint. A robotic system could aid this process by being able to transport the sensor payload into the restricted area and take readings from multiple viewpoints without the risk to humans. For both the search and rescue scenario and the routine inspection role, the robotic system required to enter this harsh environment faces the challenge of navigating and traversing very uneven terrain [6][7].

The objectives of the proposed work is to design the model of the hexapod robot on CAD Software Solid Works, analysis and simulation of the design, fabrication of the hexapod robot, controlling the robot and testing the hexapod robot.

DESIGN OF HEXAPOD

Mammals and insects serve as an inspiration for the development of robots. Mimicking their body parts and movement gives an idea of the design procedure for the robots. The robot degrees of freedom is determined by the number of actuators installed in the robot platform. A suitable power source is necessary to maintain its operation over a considerable period of time. Hence a proper number of actuators is to be installed. The operation of the robot can be controlled by using an appropriate controller.

The hexapod robot design procedure starts with determining the required components. Then the robot body is designed using design software such as Solid Works and then the body is fabricated using CNC machines. And then the body parts were assembled and the components were connected to make the hexapod. This hexapod is designed basically in order to reach the desired destination, through an uneven terrain.

Here the hexapod is provided with the wheels such that it can easily move even in the rugged surface without any disturbance to the speed and be damaging the robot. The robot is also designed in the way that it can be controlled easily with the smartphones by connecting it to Bluetooth hence ensuring the reliability of the hexapod

The developed hexapod robot with eccentric wheels is traversing an obstacle. This robot is actually symmetric in three directions. First, the robot is symmetric about the central vertical section plane in the moving direction: three eccentric wheels (#1, #2 and #3) at the left- hand side and three eccentric wheels (#4, #5 and #6) at the right-hand side. Second, the robot is symmetric about the vertical section plane passing through the axes of the middle eccentric wheels (#2 and #5). Third, the robot is also symmetric about the horizontal section plane passing through the axes of all six eccentric wheels. In other words, the upper and down parts of the robot are also symmetric about the horizontal section plane passing through the axes of all six eccentric wheels. Hence, the robot is able to walk even if it is overturned. In terms of structure, the developed hexapod is quite similar to the R-Hex robot in which open curved legs were used.

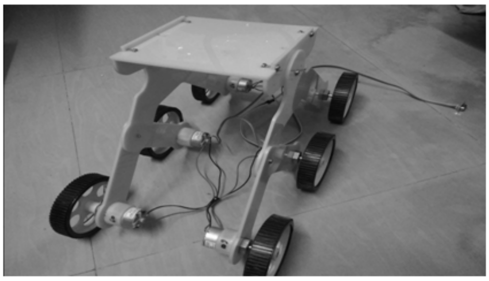

Figure 1: Final Assembly of the Hexapod Robot

FABRICATION OF HEXAPOD

A chassis was made to support the body and fix it together.. Aluminum strips of size 380x15x2mm and 190x15x2mm was cut and two pairs were made ready. The aluminum strip of 380mm long strip was used and it was bent with a radius of 10mm. The bent distance from edges is to be taken as 20 mm to make the fixation process easier. On the bent end, holes of 3 mm were drilled for accurate fixation. A hole of diameter 3 mm was drilled in the center of the body and two holes of 2 mm were drilled 15mm from the center of the body.

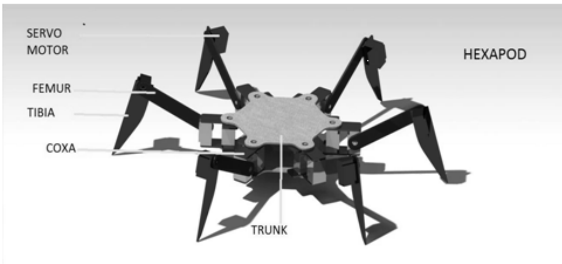

Figure 2: Fabricated Model of Hexapod Robot

A steel rod of 190 mm X 6 mm diameter was cut into three parts of 45 mm to make a crankshaft. These parts were welded with original rod using already prepared pieces of dimension 1X1 cm. Two crankshafts were made to complete the assembly. The finished crankshaft was hoisted in the 3 mm holes by nuts and bolt arrangement.

An aluminum strip of dimensions 200 mmx25mmx3mm was cut to manufacture Robot leg. A hole of diameter 6 mm was made to produce a rectangular slot of 15.5 mm x 6 mm. The slot was made at a distance of 115 mm from the ends. Two holes of 2 mm diameter were made from 6 mm distance from both edges. The purpose of drilling these holes is to adjust the height of hexapod and arm length. Wheels are attached to the robot arm for effective terrain movement. The same procedure is adopted to design all five robotic arms.

An aluminum strip of 35 mm x 30 mm x2 mm was cut to make the robot leg fixtures. A hole of diameter 2 mm was made to produce a rectangular slot of 16.5 mm x 6 mm to make robot arm. Robot leg fixture was made by drilling holes of diameter 2 mm. Eleven more parts were made. Fixing of robot leg to the crankshaft is done by placing it on the rectangular slot. Robot leg fixture is used to fix the leg by bolting with nuts and bolts of dimensions 3 mm diameter.

An Aluminium strip of dimension 155mm x 30mm x 2 mm was made and two holes of diameter 4 mm x 2 mm and 12 mmx 65 mm were drilled on the edges of a robotic arm. Similarly, five robot arms were made. A 4 mm diameter hole was drilled to fix the robot arm through a threaded shaft. Fastening of hexapod legs and arms were done by bolts and nuts.

Adhesives were made use to attach transmission gears to crank and motor shaft. Each leg was made to move with a stepper motor. The stepper shaft consisted of 16 each of diameter 45 mm. Wheels were attached to the hexapod arms for swift movement in a rugged terrain.

Hexapod Movement Analysis

Mathematical Design Calculation

The rotary motion speed at the crankshaft be $N_c$rpm and ω be the angular velocity.

Crank Velocity =V_c m/sec

Robot arm Velocity = 0.867 V_l m/sec

Robot lower leg velocity = 0.267 V_l m/sec

V_l is the linear velocity and ω is the angular velocity of the stepper motor cranks operated by gear mechanism.

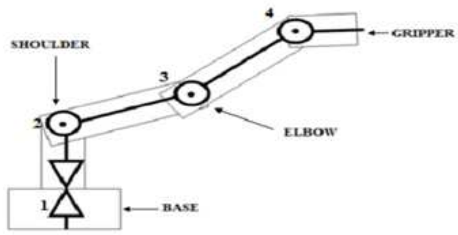

Figure 3: Image of Hexapod Arm Leg Configuration

Let the direction of crank velocity be at 90 degrees to the crank. Similarly, hexapod arm velocity is assumed to be at right angles to the robot arm. All link velocities attached to fixed point arise from the same point. Hence a triangle is obtained by dropping lines from all directions of velocities.

$\omega = 2*\Pi*N_c/60$

ω = 1.0353 rad/sec

From the velocity triangle

Robot leg angular velocity = 1.713 rad/sec

Robot leg velocity = 0.15578 m/sec.

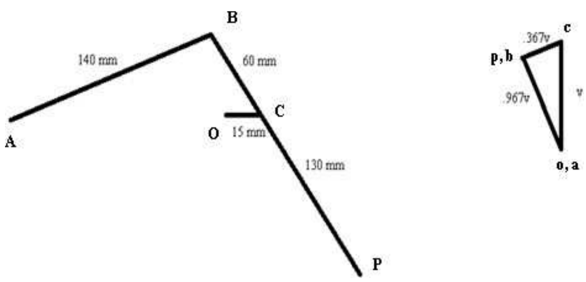

Figure 4: Line Diagram for Velocity Analysis and Velocity Triangle

Decentralized control architecture is used, where each joint can be controlled by separate servos and micro controller. The interaction of feet with the ground is one of the vital aspects to consider in robotics locomotion. And hence a feedback control for the foot force-ground interaction has been introduced. And an Algorithm was written based on the PID scheme.

RESULTS AND DISCUSSIONS

The robot was tested after the control and fabrication stage. It was controlled by a DPDT switch and has four degrees of freedom. Its motion was tested in forward and reverse direction, along with its upward and downward movement.

When the robot was tested for the first time, it was moved forward and backward. The motion was smooth, but it made noises while moving due to the presence of mechanical parts. This noise was ignored as it was unavoidable.

The following data were obtained when it was tested for the first time. The robot moved over a distance of 85 cm with a time of 6 sec. A speed of the robot was calculated after obtaining the distance and time as 0.1416 m/sec. Its speed was very close to the speed calculated theoretically.

Theoretically, the speed of the robotic leg that was obtained from the velocity analysis was 0.14469 m/sec. The difference was presumed to exist due to the slipping of the legs while moving and also due to the presence of mechanical joints without any bearings. The comparison results of theoretical and practical velocity analysis is shown in Table 1. The electronic design of robot model developed are shown in figure 5.

Table 1: Result Analysis

Details	Analytical Data	Experimental Data
Distance	85 cm	85 cm
Time	5 sec	6 sec
Velocity	0.14469 m/sec	0.1416 m/sec

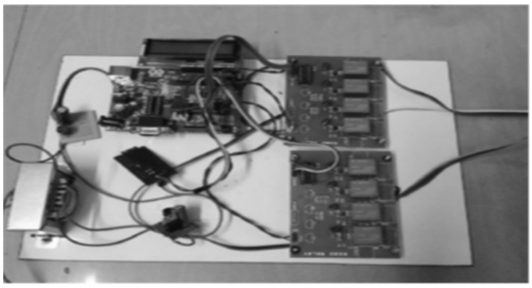

Figure 5: Prototype of Electronic Design Hexapod Robot

CONCLUSIONS

This research is motivated by the need for mobile machining systems to remove humans from hazardous and in accessible environments. The research analyzed the kinematics, dynamics requirements for a mobile machining system based on hexapod walking robots. A 3D virtual prototype robot system has been created. The design then was simulated in real time. Solid works analysis of stress and displacement deformation was carried out. Fabrication of the hexapod in line with the developed strategy was completed. Experimental demonstration of the robot and an embedment of modern technologies for productive work was done.

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